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Detection of Fat Area in Living Body Using Ultrasonic Velocity-Change Method

UVC 法を用いた生体内脂肪領域の検出

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1. Introduction

To non-invasively identify unstable plaques in the carotid artery, the ultrasonic velocity-change (UVC) method was proposed [1] and has been confirmed its validity by using the tissue phantoms [2-4]. The fat area can be detected using ultrasonic velocity change by the given temperature change of the tissue phantom.

The most important point for the realization of clinical application of this method is to remove the influence of tissue movement due to heartbeat or other mechanisms in the acquisition process of the RF echo signal needed to obtain the ultrasonic velocity change for the construction of UVC image

As one of the solutions which were not significantly affected by the heartbeat, we proposed that the RF echo signal extracted by every 0.5 sec from a sires of echo signal of M-mode installed in ultrasonography were utilized. We demonstrated that the UVC data of a carotid artery phantom under the heartbeat condition were stably obtained by using the adjacent extracted RF echo signal [4]. However, the above experiment was performed only for one-dimensional data of the tissue phantom. In this paper, we report the experimental results of the UVC method applied to the living tissue and the constructed UVC images of fat areas in the tissue.

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2. UVC method

The temperature dependence of ultrasonic velocity depends on the medium where ultrasonic waves propagate. Around body temperature, the temperature change rate of ultrasonic velocity in water is +1.9 $m\cdot s^{-1}\cdot °C^{-1}$ and that in fat is −4.9 $m\cdot s^{-1}\cdot °C^{-1}$. Using this feature, fat areas in living body can be detected. By acquiring the RF echo-signal after warming (or cooling) the tissue phantom, the fat region is identified from the temporal shifts of the RF echo-signals caused by the ultrasonic velocity change.

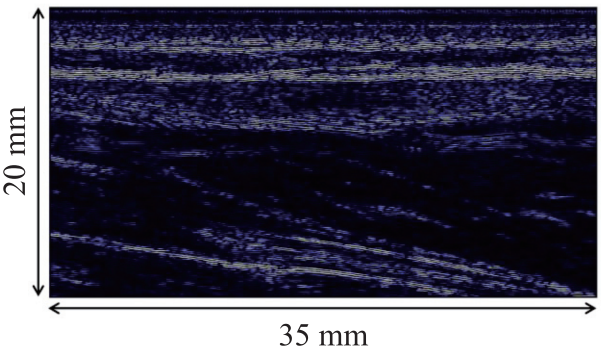

Fig. 1 B-mode image of the forearm.

3. Experiments and results

To examine the applicability of the UVC method to living body, the inner tissue of the human forearm was chosen as the target region, where the influence of heartbeat on this region is not serious. The application of the UVC method to living body was approved by the ethics committee of Osaka Prefecture University. The related experiment was performed as follows. The target region of the inner tissue of the forearm was warmed for 10 sec by a commercial ultrasonic therapy apparatus (ITO, US-711) with an output power of 0.7 W/cm^2 at 1 MHz. After warming by the therapy apparatus, B-mode images below the warmed portion were acquired continuously with an ultrasonograph (ALOKA, SSD-6500) for 9 sec at video rate.

Fig. 1 shows an example of the B-mode image, representing tissue form in the forearm. To add the information of tissue characterization on the image, the UVC method was applied. **Fig. 2** shows a variation of cross-correlation values between adjacent images acquired by the time interval of 33 ms. The cross-correlation values were calculated by the ZNCC (Zero-mean normalized cross-correlation) method using RF-signal data which construct B-mode images. Because the decreases in the cross-correlation values seen quasi-periodically in Fig. 2 were due to the heartbeat and muscle contraction, these image-pair data were removed from the total 270 image-pair data by setting a threshold value of the cross-correlation to 0.985. In this way, 88 image-pair data having high cross-correlation values were extracted in order to create UVC images.

Fig. 3 shows an example of the UVC image constructed of adjacent two images. The areas where the velocity of the ultrasonic waves became fast (slow) when the temperature decreased after warming were drawn in red (blue). Although the temperature difference (decrease) was small between the two images because the time interval was as short as only 33 ms, the temporal shifts of the RF echo-signals were detectable. The validity was confirmed from the facts that the contrast of the UVC image was improved when the target region was warmed and the temporal shifts of the RF echo-signals indicated the similar tendency among the 88 image-pair data.

To make the contrast of the UVC image higher, the 88 UVC images constructed of adjacent two images were integrated. The red layers of 8 mm thickness just below the skin surface and the blue layers below the red layers are clearly observed as shown in **Fig.4**, which are thought to correspond to subcutaneous fat layers and inner muscles, respectively.

4. Conclusion

To examine the applicability of the UVC method to living body, the construction of the UVC image of the inner tissue of the human forearm was tried. Reasonable UVC image, representing subcutaneous fat layers and inner muscles, was successfully obtained even under weak thermal stimulus. As the next study, we want to apply the UVC method to the detection of unstable plaques in the carotid artery or the estimation of the fat content of the human liver in living body.

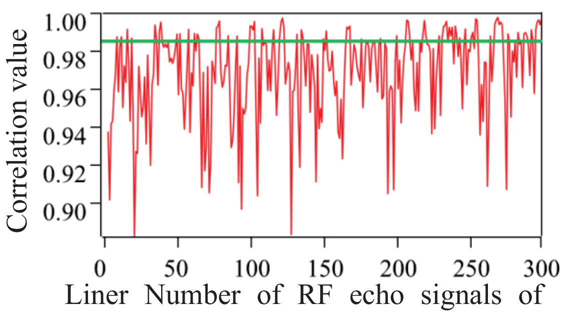

Fig. 2 Zero-mean normalized cross-correlation between adjacent B-mode images.

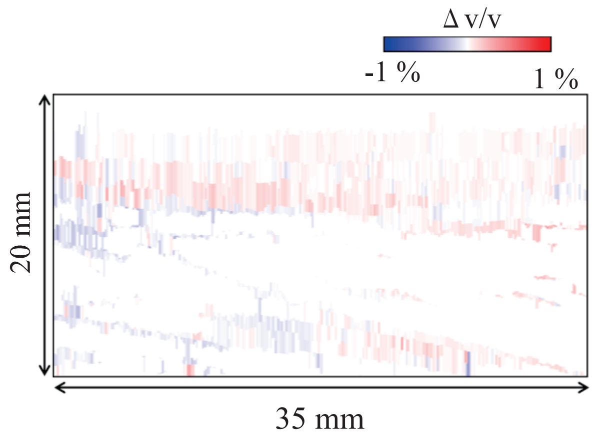

Fig. 3 UVC image of the inner tissue of the forearm constructed of adjacent two B-mode images

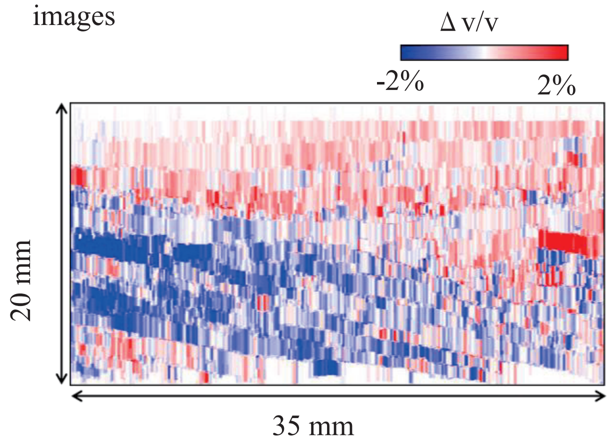

Fig. 4 UVC image of the inner tissue of the forearm integrated using 88 image-pair data.

References

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